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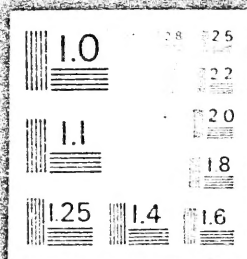
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DEVELOPMENT OF THE CEL SALVAGE,
REMOTE ASSIST AND LIFT DEVICE

J. Bayles

Civil Engineering Laboratory (Navy)
Port Hueneme, California

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report discusses the need for and development of a diver's lift assist device as a part of the Navy's salvage forces program. The device discussed in this report combines the best features of the Hunley-Wischke Remote Recovery System and the family of commercially available diver's lift assist devices. Features of the unit include buoyancy variability, inflatable, messenger capability, and reliability. It is designed to be simple, safe, and economical. A water brake designed for the device		

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proved quite effective as a safety feature in slowing the rate of ascent through the water column.

The assembly was successfully tested in the laboratory and at sea and has been forwarded to the Harbor Clearance Unit in Hawaii for in-service evaluation.

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INTRODUCTION

The Supervisor of Salvage, under delegation of authority by the Naval Ship Systems Command, has pursued a program intended to provide the latest techniques and equipment to the Navy's salvage forces. The Civil Engineering Laboratory (CEL),^a Naval Construction Battalion Center, Port Hueneme, California, sponsored by the office of the Supervisor of Salvage, has undertaken the study, design, and testing of a diver's lift assist device, and this report documents development of such a unit to aid in fulfillment of this program.

BACKGROUND

One prior development aimed at satisfying a salvage requirement was the Hunley-Wischhoefer (H-W) Remote Recovery System^b [1], a two-part system. The first part, seen in Figure 1, consists of an assembly which has limited adjustable buoyancy and which contains a packaged messenger line. A male go-getter prod, attached to the bitter end of the messenger line, is housed in the lower end of the assembly. The second part is a female overshot, Figure 2, that is used to guide a heavy-lift line down the messenger line to the male go-getter prod when the prod has been attached to an object to be salvaged.

The H-W unit also provides divers with a means of transporting the male prod directly to the object of salvage and is capable of providing limited lift for transport or salvage of other objects. It is designed to be handled in the water by one or two divers when it has been adjusted to approximately neutral buoyancy.

When the prod has been attached to the salvage object the H-W device is adjusted to the positive buoyant mode, and the buoyancy section is released to rise to the surface, streaming the connecting packaged messenger line. At the surface, the buoy and line are retrieved and brought aboard ship where the line is threaded through the female overshot and secured. The overshot is lowered by the heavy lifting line until it engages and locks to the prod. The messenger line is then detached from the prod and taken aboard ship. The salvage lift can then be made.

The H-W device was tested and performed the assigned functions, as reported in Reference 1. However, the testing revealed some undesirable

^a Formerly Naval Civil Engineering Laboratory.

^b The H-W system was designed as one component of a three-part, 25-ton lift capability, salvage system.

characteristics and focused attention on some features which could be redesigned to improve its economic aspects.

Development of another type of diver lift assist device [2,3] occurred about the same time. A family of these has since evolved. These variable buoyancy devices are invaluable diver support equipment, and similar devices are now available commercially. Several means are available for providing the buoyancy, including scuba air, bottled pressurized gas, and gas generation, and have been successfully incorporated into various models of the devices.

PROBLEMS ENCOUNTERED

Problems discovered during H-W tests and training exercises included:

1. The point of surfacing is not predictable. When the device is released at the ocean bottom its path to the surface is erratic, causing hazardous operating conditions for personnel and equipment that may be in the water column or on the surface.

2. The mass of the device and the padeye projecting from its top combine to make the device a dangerous weapon during ascent. The in-air weight of the steel device is approximately 500 pounds, exclusive of the ballast shot used to adjust major buoyancy. The device displaces about 750 pounds of seawater.

3. The messenger line is expensive and can be used only once. The line, specially wound with a reverse twist to prevent tangling as it is payed out, is encased in a tub drum. Melted wax is poured into the voids after the line is in place, then allowed to harden.

4. The buoyancy of the H-W device is varied by initially filling a ballast chamber with up to 250 pounds of lead or steel shot. The quantity used depends upon the in-water weight of any equipment to be carried or transported by the device. Shot is added to offset any remaining positive buoyancy. If too much shot is added or if the diver wishes to increase buoyancy during a dive, shot may be bled off through a small gate. If the diver wishes to reduce positive buoyancy, he may partially flood a toroidal ballast tank through valves provided for this purpose. Because this tank is relatively small, the number and extent of adjustments which can be made are limited.

5. Because of its size, the device presents a significant sail area. This makes it difficult for divers to handle in moderate currents and almost impossible to handle in heavy surf zones.

6. The male prod is retained in place by locking handles. At times divers have difficulty in removing the handles to disengage the prod. To prevent their loss, the handles are usually tethered to the device. This is a hazardous practice because the diver may become entangled in

the handles and risks being dragged to the surface. Occasionally, the ballast shot becomes lodged around the nested prod, causing it to bind and preventing disengagement.

7. All ballast shot remaining in the chamber when the prod is disengaged to permit the device to ascend is dumped through the prod housing. The costly lost shot is not retrieved.

8. The size and weight of the device necessitates the use of materials handling equipment for handling it aboard ship or placing and retrieving it over the side.

9. Economic factors other than the high costs of messenger line and ballast shot include: (1) ballast shot is a high pilferage risk item, (2) the device in its storage container and the ballast shot and messenger lines utilize valuable and limited space aboard ship, and (3) the 'specialty item' nature of the device limits its usefulness. (Though variable buoyancy diver lift assist devices, too, are specialty items, they have won Navy acceptance as valuable tools.)

APPROACH TO DESIGN OF A NEW DEVICE

Because the principles of the Hanley-Wischhoefer device and the variable lift assist devices were sound, it was recommended that a new device incorporating the best features of both be developed for the Navy's salvage forces. The new approach was to develop a diver's assist device incorporating buoyancy variability, inflatability, messenger capability, and reliability. It was to be economical, safe, and simple. In approaching the problem the factors which might limit use of the end item were established, and the concept was then developed within these constraints.

Divers and support personnel aboard surface craft are expected to handle the device with a minimum of materials handling support equipment. Therefore, minimum practicable dimensions and weight were required for the device. These requirements were consistent with the requirement that the device occupy a minimum of storage space. Based upon a minimum-sized diving team of three men, a dry weight limit of approximately 300 pounds was set for the device.

Working depth capability of Navy divers is currently limited, but commercial working depths have recently been dramatically extended. These new depths are considered pertinent to the design parameters for the new device. An extended depth capability is also desirable to provide compatibility with capabilities of small manned submersibles. A reasonable maximum depth capability, consistent with primary use by divers, is considered to be 1,000 feet for the foreseeable future. Inclusion of messenger line for 1,000-foot-depth operations was made a requirement.

Divers are limited in work capability by many factors. Endurance is directly related to effort expended. The sail area of an object handled by divers underwater is acted upon by currents and affects diver endurance

as does weight handling. The upper limit for weight to be handled in water by divers using a lift assist device was considered to be about 600 pounds. The probable mass of anything greater would possibly cause the device/load system to be too difficult to handle.

The minimum size of the device is limited by the arrangement and cube of components required to provide the desired buoyancy at a 1,000-foot-depth and to house the messenger line and male prod.

In consideration of the economic aspects, compressed gas was chosen to provide buoyancy for the prototype unit. A second generation design could incorporate a method such as the decomposition of hydrazine and any such future development could utilize the spaces occupied by the compressed gas bottles in the prototype. Either method eliminates expending expensive lead or steel shot to provide variable buoyancy. An inflatable/collapsible-bag buoyancy chamber provided with a zippered closure, vertically oriented in its sidewall, serves as the buoyancy chamber. The collapsible buoyancy-bag, when properly placed and inflated, will also serve as a soft nose or bumper to reduce the hazards of its ascending beneath equipment or personnel.

The rate of upward acceleration of the device is mainly dependent upon its positive buoyancy and drag factors. The messenger line does not contribute significantly to the drag factors for the H-W system because the line is payed out without restraint. In a new design, the line could be utilized to slow the rate of ascent and absorb some of the energy. One method would use the line to rotate a reel as the line payed out. A brake automatically applied to the reel would convert some of the energy. The brake could be of the water-brake type. Other design features of the reel and the method of attaching the messenger line to it could provide a means for recovery and reuse of the line.

To achieve approximate neutral buoyancy, the new design could utilize either low density materials or one-atmosphere voids to offset use of high density materials where required.

Figure 3 illustrates a conceptual arrangement in which each of the above items has been considered.

DESIGN OF CONCEPT

The design as developed by CEL utilizes two major subassemblies.^c

Design of the first subassembly began by finding package dimensions for the compressed gas required for a 600-pound lift capability at a depth of 400 feet. Design parameters included vertical orientation of the device. The most readily available off-the-shelf source of this compressed gas packaging is the common scuba bottle. One '72' scuba bottle will provide approximately 320 pounds of buoyant lift at a 400-foot depth. Although this capacity does not provide the full 600-pound lift capability,

^c Naval Civil Engineering drawings 71-40-1F through 4F are available on request.

three such bottles will provide adequate gas for a number of adjustments in lift capability at usual diver work depths and will accommodate an emergency lift of approximately 360 pounds at a 1,000-foot depth. More recent scuba bottle developments could enhance this capability. The three bottles are vertically oriented and symmetrically arranged around the vertically oriented lift bag. The bottles are mounted between the walls of a hollow-cored, cylindrical, fiber glass housing. The three individual bottle housings in the subassembly are large enough to provide mounting space for gas generation systems which could provide far greater or more extensively variable buoyancy capability at deeper depths.

Approximately the upper half of the hollow core of the first subassembly houses the inflatable bag any time it is in the collapsed mode. The bag^d is attached to a load transfer ring member mounted within the core of the subassembly. The lower half of the core area accommodates the reel of messenger line, mounted on the second subassembly, when the two subassemblies are assembled together.

The second subassembly is fabricated from a fiber glass structure having a flat upper surface, a centrally mounted spindle and the inflation gas manifold. A stator ring assembly is mounted concentrically on the flat upper surface of the fiber glass base. The spindle serves as the axle for the messenger line reel. The lower flange of the messenger line reel serves a second purpose as a centrifugal pump. The external face of the flange has integral radial vanes which rotate within the stator ring when the reel is turned. Because its discharge is restricted, this pump acts as a water brake. The spindle also serves other purposes. A ring at its lower end serves as a load attachment point. The spindle is hollow throughout most of its length. The hollow portion extends downward through the upper face of the fiber glass base. An entry is drilled and tapped into the hollow spindle at a point below the upper face of the fiber glass base and the gas manifold is mounted in this opening. A check valve is mounted in the upper end of the hollow spindle to prevent water entering the scuba bottles when the bottle internal gas pressure is less than the ambient water pressure.

The two subassemblies, when assembled, are locked together by fasteners mounted around the circumference. When a load is supported underwater by the lift assist device, the stress is transmitted from the load attachment ring through the spindle to the lower fiber glass structure, thence through the lock fasteners into the side-wall of the upper fiber glass structure and then to the inflated bag by its attachment bolts.

When the two subassemblies are joined together, the design provides a 'tunnel' through which the messenger line is threaded. A line guide is mounted on the lower extension of the reel mounting spindle, and the messenger line is threaded through this. The line is then attached to the male prod, or to any other intended object. The line guide acts to approximately center a load on the messenger line below the device.

^d Uniroyal drawing FCD 52219 as modified by CEL.

The manifolding for the inflation gas includes first stage regulators for mating to the scuba bottles.

When the device is assembled, the upper end of the reel spindle is held in position along the central axis by inserting the check valve into a centering bracket mounted in the upper subassembly.

Hollow, 2-inch-diameter, buoyancy spheres fill spaces between the scuba bottle housings in the upper fiber glass double-walled structure. These spheres are rated to withstand water pressure at depths to 1,000 feet. Their purpose is to provide buoyancy to offset excess in-water weight of the high density material used in fabricating the device. The quantity of these spheres can be varied to adjust the positive/neutral/negative buoyancy condition of the device.

The design characteristics of the device are:

Height, with bag inflated.....68 inches
Height, with bag collapsed.....32 inches
Diameter.....36 inches
Bag Diameter.....20 inches
Weight, dry.....320 pounds
Weight, in-water.....adjustable, nominal neutral

(with male prod)

Lift, with bag collapsed.....approximately 20 pounds

(without male prod)

Lift, with bag inflated.....approximately 570 pounds

(without male prod)

Messenger line, 1/2-inch diameter, braided
Capacity..... 750 feet
Breaking strength.....4,200 pounds

Messenger line, 3/8-inch diameter, braided
Capacity.....1,000 feet
Breaking strength.....2,700 pounds

The device can be adjusted to a slightly positive buoyant condition when it is to be used in streaming a messenger line between an object on the bottom and the water's surface. This adjustment occurs when the male prod is detached from the device. However, if the prod is not to be detached the condition can be attained by adding the required number of small flotation spheres. The buoyancy bag need not be inflated. There may be occasions, however, when divers will find it necessary to increase the buoyancy by adding inflation gas. In these situations the diver controls the effective buoyancy by properly setting the zipper slide along its vertical track. This capability also provides the diver with the option of sending light loads to the surface without deploying the messenger line.

TEST PROGRAM

Surface Tank Tests

The device, Figures 4 through 6, was tested first in the 10-foot-deep diving tank at CEL. All features performed as intended and divers reported that in its neutrally buoyant mode the device could be easily maneuvered and delivered to the bottom by one man swimming without benefit of swim fins. Because of the absence of water currents in the tank, divers reported the device could be controlled at the bottom site by effort of only one finger. Divers using the device also reported that they had no difficulty in performing all required underwater operations, including disengaging the restraining bridle that keeps the collapsed bag housed, manipulating the bag closure zipper to adjust buoyancy, re-collapsing the deployed bag and stowing the bag in its compartment. The divers easily maneuvered a 600-pound load from location to location on the tank bottom.

With the inflation bag in collapsed mode and with the messenger line tethered to an object on the tank bottom, the line payed out without problem as the device rose to the surface. In this mode the device ascended very slowly and could not have caused damage to any object at the surface. The device was not released from the bottom with the buoyancy bag inflated because the diving tank was too shallow to test the effectiveness of the water brake.

All of the tests in the tank were witnessed through viewports in the tank side walls.

Divers recommended the following modifications to further ease the efforts required in handling and operating the device underwater:

1. Provide a larger and more rigid tab on the zipper slide.
2. Provide a hand grip at the top of the bag to be used to improve diver control of the zipper.
3. Provide a short strap or chain on the load attachment ring.
4. Enlarge the vents in the lower fiber glass structure to facilitate release of entrapped gases.
5. Modify the bag retaining bridle by providing a larger ring for attaching the snap or by providing a snap with a better hand grip.
6. Relocate the gas inflation control valve to improve accessibility.
7. Consider providing a means to assist the diver in repacking the bag when it has been deflated underwater.

Tests at Sea

Tests at sea, performed in water 66 feet deep, were undertaken to determine the effectiveness of the water brake and to test handling characteristics of the device at sea. The effectiveness of the water brake is crucial to control of the rate of ascent of the device when the bag is inflated. The messenger line must be employed to activate the brake.

The four ascent modes tested were:

1. Release of the device at the bottom without increasing inherent buoyancy and without employing the messenger line.
2. Release without increasing buoyancy but with employment of the messenger line.
3. Release with complete bag inflation but without line employment.
4. Release with maximum buoyancy and with the line employed.

Test results indicated that the water brake used in tests 2 and 4 effectively limited the ascent velocity of the device. The ascent rates of these tests were significantly lower than ascent rates of tests 1 and 3. The ascent rates observed in tests 2 and 4 would not endanger personnel or equipment. Divers found the device was easily handled and operated in the open sea in the absence of strong currents and heavy surf conditions.

DISCUSSION

The following observations were noted during the testing program and should be considered in production design.

The prototype device used in these tests had to be handled with care because the methods used in assembling the fiber glass structure are not recommended for production models. It was built to test a concept and can not take extreme abuse, such as dropping it into the water from the deck of craft, but should be lowered into the water by line. Future production models can be constructed to withstand rough treatment.

During the program insertion and extraction of the scuba bottles was facilitated by rotating them during the process. Future models should ease the feature.

The messenger line must be neatly level-wound on the reel (under slight tension) to prevent its binding between underlying wraps when a strain is taken. If binding occurs it could prevent the line from being payed out and abort an ascent. To assure that the line remains firmly wound on the reel, a small stopper line should be passed through the two holes provided for locking the lower flange of the reel to prevent its turning. After the reel has been secured in this manner,

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the messenger line must be drawn taut and stopped off. The two small stopper lines can be severed by the diver when the device is rigged for release.

Devices of this type can be easily modified to include at least three additional scuba bottles. This would increase the dry weight, but would not affect the in-water weight of the device and would not increase its size. The added gas capacity could be used to increase the number of buoyancy adjustments possible or to enhance lift capability at deeper depths. The added bottles could also be provided a separate manifold and be used as an auxiliary or emergency breathing gas supply.

All of the recommendations made by the divers were considered appropriate. The changes suggested by the divers after the tank tests were incorporated in the prototype design for the sea tests. In addition, to assist the diver in repacking the collapsed inflation bag, a vent valve was added at the top of the bag to permit bleeding off any pocket of gas remaining after the zipper slide has been fully raised.

CONCLUSIONS

The device satisfactorily met the planned test objectives and was forwarded to the Harbor Clearance Unit stationed in Hawaii for in-service evaluation.

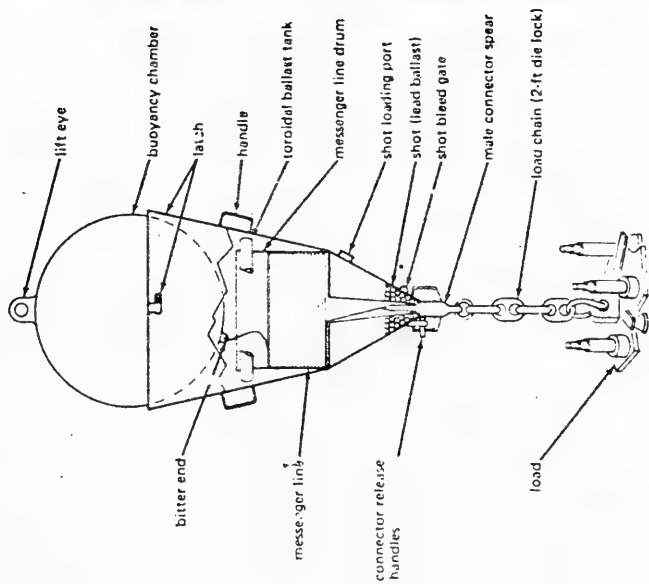
RECOMMENDATIONS

It is recommended that future fabrication of such devices utilize conventional methods of laminating joints with glass fabric and resin. The prototype fiber glass structure was assembled by making epoxy fillets instead of reinforcing the junctures with fiber glass mat and resin. During tests the joints proved too brittle to take shock loading when the device was dropped into the water.

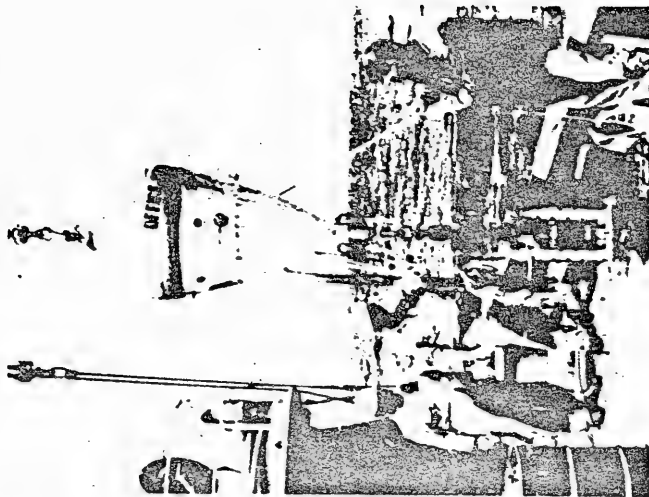
It is recommended that the buoyancy bag be inflated only for assisting with load handling and streaming messenger lines and not be employed to send the device to the surface free of a tether unless for some special purpose partial inflation is required. In such instances inflation should be limited to the minimum required, by setting the zipper slide at a proper location.

ACKNOWLEDGMENT

The author wishes to acknowledge the assistance of the CEL diving division personnel and Mr. John Hittlerman during the diving phases of the development and testing.

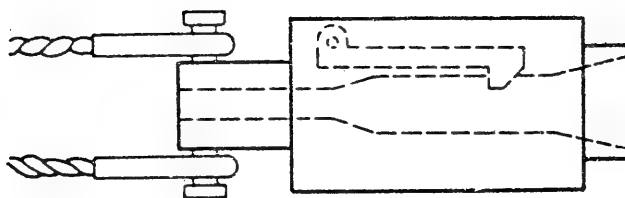


(a) Sectional view.

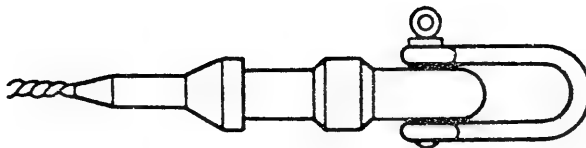


(b) Assembled view.

Figure 1. Hunley-Wiathhoefer assembly with 25-ton payload.



(a) Female overshoot device



(b) Male connector spear (prod).

Figure 2. Hunley-Wischniwofer female overshoot and spear.

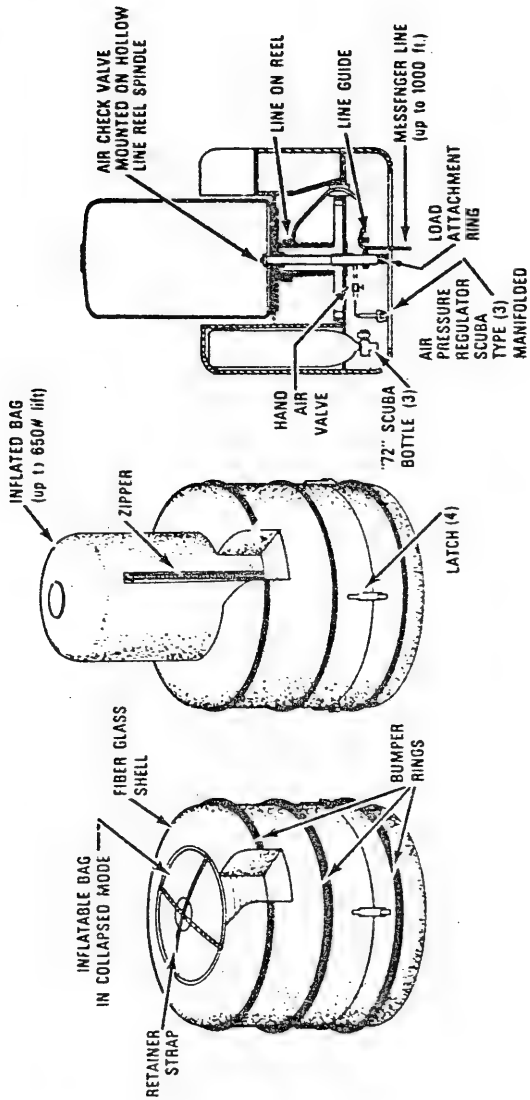


Figure 3. Three views of CEL lift device



Figure 4. Lift device floating free at surface.

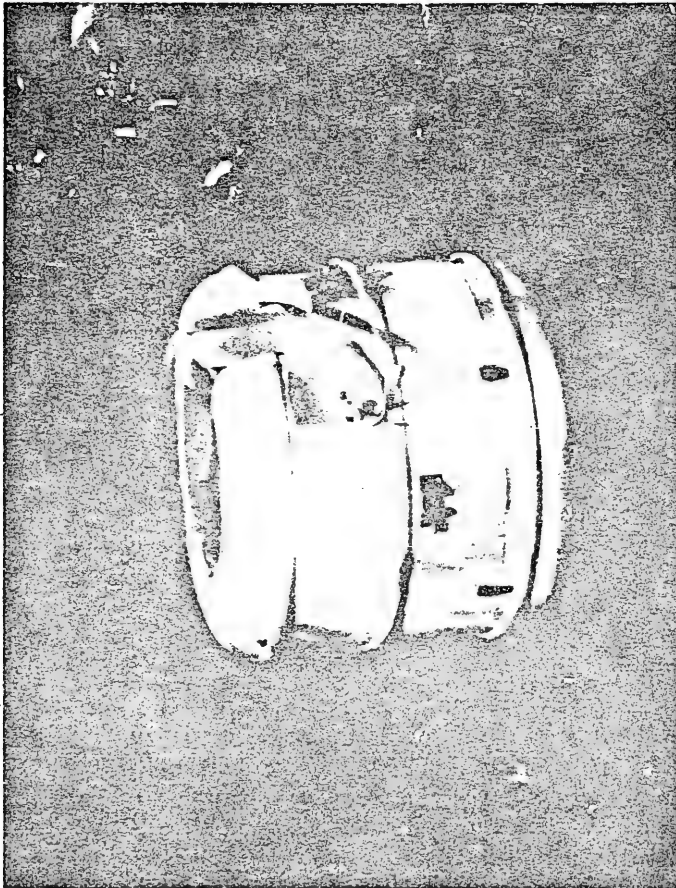


Figure 3. Diver swimming with the lift device.

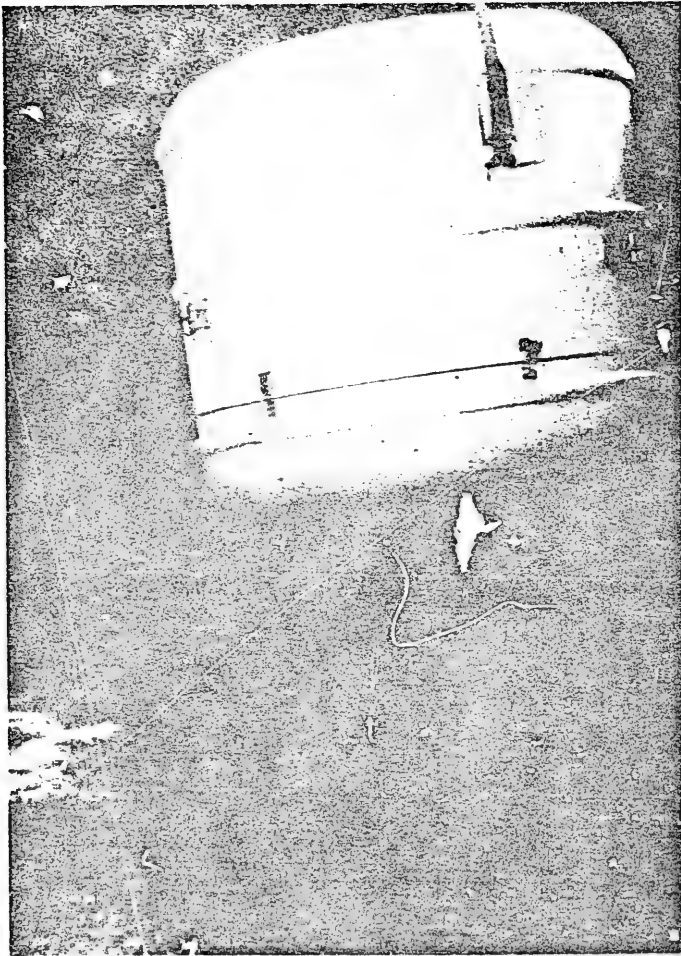


Figure 6. Device tethered to bottom of test tank.

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